

## F-16 UCAVs

### A Bridge to the Future of Air Combat?



MAJ CHIP THOMPSON, USAF

*New World Vistas also "got too focused" on high-performance unmanned fighters. I think UAVs [unmanned aerial vehicles] are moving in the right direction—that is, initially, we'll use them for intelligence, surveillance, reconnaissance and hopefully for longer dwell, greater survivability kinds of things. In the longer term, though, we'll have to look at whether a "smart" UAV is really the way to deliver weapons.*

—Gen Ronald Fogleman



PROMPTED BY ISRAELI UAV combat successes and the remarkable performance of the Israeli-built Pioneer UAV flown by the US military in Desert Storm, the Department of Defense (DOD) is now actively pursuing new US-built UAV systems. Starting with subscale drones in Vietnam, the DOD effort has focused primarily on the surveillance and reconnaissance mission for UAVs. A major milestone for mili-

tary UAV programs occurred in 1996 when the US Air Force started its first UAV operational squadron near Las Vegas, Nevada, flying the medium-altitude Predator surveillance and reconnaissance platform. In 1999, numerous Predator missions provided invaluable intelligence information to North Atlantic Treaty Organization (NATO) commanders and targeteers in the air war against Serbia.

Report Documentation Page				Form Approved OMB No. 0704-0188	
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.					
1. REPORT DATE <b>2000</b>		2. REPORT TYPE		3. DATES COVERED <b>00-00-2000 to 00-00-2000</b>	
4. TITLE AND SUBTITLE <b>F-16 UCAVs. A Bridge to the Future of Air Combat?</b>				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) <b>Air and Space Power Journal, 155 N. Twining Street, Maxwell AFB, AL, 36112-6026</b>				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT <b>Approved for public release; distribution unlimited</b>					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT <b>Same as Report (SAR)</b>	18. NUMBER OF PAGES <b>15</b>	19a. NAME OF RESPONSIBLE PERSON
a. REPORT <b>unclassified</b>	b. ABSTRACT <b>unclassified</b>	c. THIS PAGE <b>unclassified</b>			



*Predator medium-altitude UAV*

The USAF is currently researching other combat mission ideas for UAVs, including suppression of enemy air defenses (SEAD) at a “battlelab” in Eglin AFB, Florida. However, the DOD, in particular the USAF, has not prioritized or funded any substantial research into a bomb- or missile-carrying lethal UAV or unmanned (or uninhabited) combat air vehicle (UCAV). The USAF Scientific Advisory Board’s *New World Vistas* report, the Defense Advanced Research Projects Agency (DARPA) office, and the Air Force 2025 project have all called for the rapid development of UCAVs. Military planners, industry experts, and scientists all agree that current “off the shelf” technology is adequate to field an effective UCAV platform. Yet, the USAF is reluctant to trust an unmanned remote-control aircraft with the responsibility of dropping bombs or shooting missiles. Due to defense budget cuts and competition from the manned F-22 Raptor and Joint Strike Fighter (JSF) programs, the operational fielding of new-technology UCAVs is decades away. In 1997, Gen Ronald Fogleman, USAF chief of staff, and Col Joe Grasso, the Eglin UAV battlelab commander,

stated that lethal UAVs would not fly for at least 25 years.<sup>1</sup>

In the meantime, US military and political leadership must continue to rely on cruise missiles to deal with conflicts where the potential loss of American lives is unacceptable. Today, sea- and air-launched cruise missiles are the only offensive military instruments of power guaranteed not to produce US casualties or prisoners of war (POW). However, the current US stockpile of cruise missiles has ordnance limitations that prevent them from attacking important “hardened” military targets such as command and control (C<sup>2</sup>) bunkers, underground weapons storage facilities, or armored vehicles. Even though the USAF and US Navy are now researching penetrating warheads and in-flight reprogramming, these new air- and sea-launched cruise missiles will still not reach the combat flexibility and capability of a modern multirole fighter. Finally, the United States has only a limited number of the one-million-dollar-plus expendable cruise missiles. This surprised many in the spring of 1999 when the Pentagon placed an emergency order for more air-



Northrop-Grumman's future-concept UCAV

launched cruise missiles only a few days into the air war in Kosovo.

Because of current cruise missile target restrictions, limited numbers, and the high costs associated with a "one-shot" delivery platform, US leaders need another unmanned military option today that can destroy most potential enemy targets and can be reused for cost-effectiveness. UCAVs can provide this additional unmanned military alternative to cruise missiles. Yet, as previously stated, new advanced-technology UCAVs are decades from operational fielding. Can the USAF quickly provide a cost-effective UCAV option to US leadership in the interim?

The USAF can quickly provide a cost-effective unmanned military option by modifying some F-16C fighters into dual-role UCAVs. The multirole F-16 is a combat-proven air-to-air and air-to-ground fighter platform that can perform all airpower missions with its capability to carry almost all of the USAF bomb and missile inventory. Slightly modifying an F-16C for unmanned flight while maintaining its manned flight capability gives the USAF most of the advantages of UCAV operations and reduces or eliminates many unmanned flight concerns. A remotely piloted, dual-role F-16C UCAV can quickly provide a politically safe, cost-effective, and flexible unmanned military option for US leadership.

An important prerequisite for this F-16 UCAV idea is proving that the United States now needs an alternative to cruise missiles. Therefore, this article presents arguments on why US leadership quickly needs an interim

UCAV option before exploring the F-16C UCAV proposal. The objectives of this article are to (1) provide some UCAV background to the reader with the advantages and concerns related to unmanned flight, (2) explain why the United States needs an interim UCAV military option, and (3) recommend the dual-role F-16C UCAV. In summary, this article addresses two important issues. First, the United States needs an interim UCAV option to overcome cruise missile limitations as soon as possible, and second, a dual-role F-16C UCAV can quickly and effectively fulfill the requirements for this interim unmanned military option.

## UCAV Research

Prompted by the USAF Scientific Advisory Board's recommendations in *New World Vistas*, DARPA research grants, and UCAV interest in the Air Force 2025 project, several US aerospace companies including Teledyne Ryan, Boeing, Northrop, and Lockheed Martin have started preliminary designs on advanced-technology UCAVs. Both Great Britain and Germany are also studying a UCAV replacement for their air-to-ground Tornado. Interestingly, the development and research phase of the Joint Strike Fighter now has four versions: USAF, USN, US Marine Corps, and a UCAV. Dr. Gene McCall, USAF chief scientist, predicts that the last JSFs to roll off the factory line will be UCAVs.<sup>2</sup>

Advancing technology, politics, and, most important, smaller military budgets may eventually persuade the USAF to operate unmanned lethal aircraft for most combat missions in the future. Primarily because UCAV "operators" conduct routine training in simulators, DARPA and other aerospace companies have suggested that UCAVs will save 55 to 80 percent in flight operations and support costs compared to manned systems.<sup>3</sup> Lower maintenance, training, and operation costs are only some of the advantages of UCAVs over traditional manned fighter aircraft. Table 1 lists some UCAV advantages over manned aircraft, and table 2 presents some concerns for future UCAV operations.

The USAF can overcome many UCAV concerns with experience and development of safe procedures and doctrine. Some, especially the security and protection of the critical UCAV C<sup>2</sup> links, may require new emerging technologies in communications such as data compression and data-burst transmissions. The USAF's vision of the capabilities expected from future UCAVs is expressed in the following excerpt from the *Air Force 2025* Strikestar executive summary:

In 2025, a stealthy UAV, we refer to as "Strikestar," will be able to loiter over an area of operations for 24 hours at a range of 3700 miles from launch base while carrying a payload of all-weather, precision weapons capable of various effects. Holding a target area at continuous risk from attack could result in the possibility of "air occupation." Alternatively, by reducing loiter time, targets within 8500 miles of the launch



Tomahawk cruise missile

and recovery base could be struck, thus minimizing overseas basing needs.<sup>4</sup>

### Reasons for an Interim UCAV

As previously stated, it will take the USAF decades to put advanced-technology UCAVs

Table 1

#### Advantages of Future UCAVs over Manned Aircraft

Vehicle Cost	Cheaper to build since pilot requirements such as cockpit controls and gauges, ejection seat, oxygen, canopy, and pressurization are unnecessary. Saves about 10 percent on overall vehicle cost, including remote-control equipment. Some advantages negated by remote ground-station costs.
Range and Endurance	Longer flight times and ranges due to less drag and better engine placement without the canopy and cockpit. No human limits on flight-endurance time. Some UCAVs may fly for days over enemy territory.
No Crew Risk	No political risk from casualties or POWs. Can employ nonlethal weapons to put an enemy to sleep such as acoustic or brain-wave manipulation. Can operate in a nuclear, biological, or chemical environment with no risk to the pilot.
Survivability	Unmanned design without a canopy makes aircraft smaller and lowers radar cross section. Absence of humans permits high 10G-plus turns to avoid enemy missiles.
Training	Most training for UCAV operators is in simulators. No dependence on weather or maintenance-ready aircraft. Periodic exercise participation such as Red Flags to test doctrine and manned-flight interface.
Training and Support Costs	With only periodic flight training and little to no maintenance on the majority of "stored" UCAVs, there is a large reduction in peacetime training, fuel, and maintenance support costs.
Personnel	Fewer pilots and support personnel are needed. UCAV operators can fly numerous UCAV sorties sequentially or at the same time. With few training flights, fewer maintenance personnel and less equipment are required.

**Table 2**  
**Future UCAV Concerns**

Datalink Communications	<ol style="list-style-type: none"> <li>1. Loss of control due to enemy jamming or signal manipulation</li> <li>2. Long connectivity lapses due to distance, satellite location, or friendly mutual interference</li> <li>3. Limited amount of frequency bandwidths to accommodate large numbers of secure links for multiple UCAV operations</li> </ol>
Air Refueling	<ol style="list-style-type: none"> <li>1. Transoceanic deployment distances and communications</li> <li>2. Risk to KC-135 or KC-10 high-value assets</li> <li>3. Tanker joinup and multi-aircraft air refueling</li> </ol>
Operator Situational Awareness	<ol style="list-style-type: none"> <li>1. Number of aircraft per operator or operators per aircraft</li> <li>2. Air traffic control (ATC) and enemy airspace deconfliction from other aircraft</li> <li>3. Threat reactions for visual anti-aircraft artillery, infrared surface-to-air missiles, or enemy aircraft</li> </ol>
Emergencies	<ol style="list-style-type: none"> <li>1. Less capability to rapidly assess and correct aircraft problems</li> <li>2. Unable to see damage, feel small vibrations, or smell smoke</li> <li>3. UAV-capable alternate airfield recovery due to fuel or weather</li> </ol>

into operational status. So why spend money on an interim UCAV? Cruise missile advocates argue that improvements to the sea-launched Tomahawk and the air-launched AGM-86 can handle high-risk missions for the next 20 years. However, even the improved versions of air- and sea-launched cruise missiles will still have some target limitations, and the more expensive costs for hard-target penetration and reprogramming may restrict their numbers. In addition to cruise missiles, Air Force planners point out that new "standoff" launch-and-leave weapons such as the joint standoff weapon (JSOW) and the joint air-to-surface standoff missile (JASSM) can destroy targets without risking lives. Although these expensive standoff weapons do put the aircrew farther from the target area at release, they may still expose the aircrew to enemy threats outside the immediate target area.

There are political, economic, and military reasons why the United States should immediately take steps to reap the advantages of UCAVs over manned aircraft. Although political advantages are inherent to both UCAVs and cruise missiles, the economic and military

advantages to UCAVs overcome some cruise-missile limitations.

#### ***Political***

UCAVs provide US political leadership another military-instrument-of-power option that will not risk American lives. In smaller-scale conflicts, the threat of losing a pilot and—even worse politically—the prospect of the enemy holding a POW have motivated President Bill Clinton to rely primarily on cruise missiles for post-Desert Storm standoffs against Iraq or for retribution against terrorism. The overwhelming national response to the Scott O'Grady shootdown and the size and complexity of his rescue have reinforced the value of a single human life in military missions to the president and Congress. For example, the *Washington Post* ran a front-page story for three straight days after the O'Grady shootdown. Yet, two months later when two Predator UAVs were lost over Bosnia, the same newspaper devoted only one small back-page article.<sup>5</sup>

Trying to plan effective and efficient military missions with zero loss of life is the almost

impossible task given to military planners today. Not only will UCAVs give war planners more options, the capabilities of UCAVs to strike all types of targets without loss of life represent an important deterrent to US enemies. A combination of UCAVs and cruise missiles will better enforce United Nations (UN) resolutions against tyrants such as Saddam Hussein or Gen Ratko Mladic, the Bosnian Serb commander who remarked that “the Western countries have learned they cannot recruit their own children to realize goals outside their homelands.”<sup>6</sup>

#### **Economic**

Reusability is one of the key advantages of UCAVs over expendable cruise missiles. Tomahawk cruise missiles today cost between 1.1 and 1.2 million dollars per shot, with over 250 launched in the first week of Desert Storm alone.<sup>7</sup> In contrast, a five-million-dollar reconditioned “boneyard” F-16 converted into a UCAV would become more cost-effective than a cruise missile in fewer than eight flights, adding a conservative three million dollars for bombs, fuel, and one year of maintenance support. It is important that a UCAV is survivable for repeated missions, or it quickly becomes a very expensive cruise missile. Nonstealth UCAVs may need SEAD to survive a high-threat area with numerous surface-to-air missiles (SAM), or they may require air-escort protection through areas without air superiority.

By modifying existing or retired fighter or bomber airframes into unmanned remotely piloted aircraft, the USAF can have an interim UCAV program that saves the expensive research and development costs associated with a new aircraft. New technology is not needed to modify an existing airframe into an interim UCAV—only inexpensive off-the-shelf systems. The USAF will realize additional cost savings at the end of the interim UCAV program since Tyndall AFB, Florida, can use the retired UCAVs for air-to-air missile testing and save the current conversion expense of turning boneyard fighters into target drones.

With unmanned aircraft, another economic benefit is the reduced requirement for combat search and rescue (CSAR) resources. Not only high operational costs but also high

---

***An interim UCAV can carry a variety of ordnance to destroy most enemy targets, and with “semiautonomous” flight, a human operator can identify the target area and consent to ordnance release.***

---

temporary duty (TDY) rates affecting quality-of-life issues are continuous USAF concerns in maintaining a CSAR alert force for the UN and NATO missions in Iraq and Bosnia.

#### **Military**

Long-range sea- and air-launched cruise missiles will always remain an important capability for the US military because of survivability and no requirements for forward basing. However, cruise missiles currently have ordnance limitations that restrict them to attacking only fixed-position “soft” targets. Another limitation due to the cruise missile’s full automation is the lack of man-in-the-loop target identification and consent for release of weapons. On the other hand, an interim UCAV can carry a variety of ordnance to destroy most enemy targets, and with “semiautonomous” flight, a human operator can identify the target area and consent to ordnance release. In addition to increased target selection, other important military reasons to operate an interim UCAV include man-in-the-loop target verification and an improved transition to an unmanned Air Force.

**Target Selection.** One advantage of a UCAV over today’s cruise missile is its ability to deliver a variety of ordnance. Currently, cruise missiles can carry only a thousand-pound explosive or about six hundred baseball-sized “grenades.” These ordnance loads restrict military planners today to a single “soft” enemy target such as a radar dish or unsheltered aircraft. In addition, even if some



*Iraqi bunker destroyed by a laser-guided bomb*

future cruise missiles are capable of in-flight target reprogramming, they will still have difficulty hitting moving targets such as armored vehicles.

Air Force Systems Command is aware of the soft-target limitation and is planning to test AGM-86C cruise missiles with a thousand-pound penetrating warhead in hopes of providing this capability in two to three years.<sup>8</sup> However, these advanced cruise missiles have new terminal seekers that have not yet been verified to be as accurate as current laser- or TV-guided bombs. A successful attack on a small hardened bunker or underground facility usually requires a three-meter or less circular error probable (CEP) for "air vent accuracy" and may require more bomb weight for deeply buried targets. For many "hardened" targets, the Joint Munitions Effectiveness Manuals (JMEM) require near-simultaneous, multiple two-thousand-pound bombs for destruction, much more than a cruise missile's single penetrating thousand-pound warhead.

On the other hand, a UCAV-modified F-16C can fly the necessary altitudes, airspeeds, and dive angles to deliver the right ordnance to destroy most enemy target types—for example, the target-penetrating two-thousand-pound, steel-encased, GBU-24I laser-guided bomb. Reprogramming target coordinates in the air with the new joint direct attack munition (JDAM) or Global Positioning System (GPS)-guided JSOWs give a future interim

UCAV the ability to destroy targets in any weather condition.

Mobile Scud missile launchers, SA-6 SAM sites, or columns of tanks are not viable targets for a cruise missile because its accuracy depends on the programming of correct target coordinates before launch. However, an F-16C UCAV could use its GPS, radar in the ground moving target (GMT) mode, and the forward looking infrared radar (FLIR) targeting pod to find moving vehicles on which to drop five-hundred-pound laser-guided bombs (LGB) or shoot Maverick missiles. In Desert Storm, a moving vehicle was the easiest to find and destroy since it was not buried in sand for protection or camouflaged to prevent identification. An unmanned F-16C carrying GBU-12s can work with a joint surveillance, target attack radar system (JSTARS) aircraft for real-time target position updates to quickly destroy up to six moving vehicles.

**Man-in-the-Loop Target Verification.** Even with terrain updates and target photo matching, a cruise missile does not always find the correct target. Mechanical errors such as a drifting inertial navigation system (INS), loss of GPS signal, or human errors in entering the wrong target coordinates always put some doubt in the launcher's mind. Without real-time target validation just prior to bomb release, many potential targets located near politically unacceptable areas such as hospitals, schools, or residential neighborhoods may remain untouched. An interim UCAV, however, with man-in-the loop semiautonomous flight control can identify the target area and consent to ordnance release. The ground remote-control operator receives real-time optical, infrared, or radar-mapping pictures of the target area and sends back, if needed, target position updates or corrections. When the human operator verifies that the unmanned aircraft is attacking the correct target, consent to release weapons is sent to the UCAV.

Even manned systems with enemy target identification technology are not completely reliable. For example, in Desert Storm an errant high-speed antiradiation missile (HARM) from an F-4G guided towards the



tail of a B-52, and the US Navy fired on one of its own aircraft. Until the US military is comfortable that artificial-intelligence weapon systems will not kill friendly troops, man-in-the-loop control will allow unmanned systems in the interim more flexibility in combat missions. Unlike cruise missiles with one mission (strategic attack), UCAVs carrying a variety of ordnance with man-in-the-loop control can conceivably fly SEAD, battlefield air interdiction (BAI), and offensive counterair (OCA) missions. Later, with more interim UCAV experience and acceptance, the USAF may allow missions to expand to close air support (CAS) and defensive counterair (DCA).

One more consideration for a UCAV man-in-the-loop control system is its ability to defend itself if attacked. Although cruise missiles rely on small size and radar cross section to survive to the target area, slow subsonic speeds and better radar technology are becoming cruise-missile survival concerns to the USAF. Since air defense exercises of the North American Aerospace Defense Command (NORAD) routinely practice F-16 and F-15 air intercepts to destroy simulated enemy cruise missiles, the US military must believe that future radars can detect and send modern aircraft such as the Su-27 Flanker or the Mirage 2000 to destroy defenseless subsonic US cruise missiles. An interim UCAV fighter, however, can carry advanced medium-range, air-to-air missiles (AMRAAM) for protection and use man-in-the-loop control to help prevent fratricide. With enemy aircraft confirmation from the airborne warning and control system (AWACS) or Rivet Joint aircraft, a future war may produce the first ground-station remote-control-operator "aces."

**Transition to the "Pilotless" Air Force.** Technological advances, funding, and political pressures may eventually force most combat aircraft that fly over enemy territory to be pilotless by the mid-twenty-first century. An interim UCAV program will help ease this transition by exposing pilots to the distinct advantages of unmanned flight and, more importantly, by working out many of the "bugs" for implementation of advanced-technology

UCAV systems. For example, the Federal Aviation Administration (FAA) has been avoiding control and deconfliction of UAVs and civilian air traffic for years. The operational fielding of the Predator and its peacetime training requirements in US airspace have forced the FAA to begin seriously working unmanned-aircraft issues.<sup>9</sup>

## F-16C UCAV

With years of experience turning mothballed fighters into full-scale target drones, remote-control engineers can convert any of the US military's aircraft for unmanned flight. So why is the F-16 the best candidate for an interim UCAV? Because the F-16 is a multirole fighter, it performs all USAF missions such as SEAD, DCA, OCA, killer scout, deep strike, interdiction, and CAS. No other current aircraft in the US military can explore unmanned doctrine in so many areas of air combat. Not only are the F-16s comparatively inexpensive aircraft weapons systems to procure and operate, they are more numerous than all other interim UCAV candidates combined, including the A-10, F-15E, F-117, B-1, and B-52. This would help the F-16 community better absorb an initial testing or operational mission loss versus a more expensive and less numerous high-value asset such as an F-117 or F-15E. The small size and superior maneuverability of the F-16 also increase its survivability over larger bombers such as the B-1 or B-52.

An interesting interim UCAV solution offered by Lockheed Martin Tactical Aircraft Systems (LMTAS) is to modify older F-16A jets baking in the Arizona sun at the Davis-Monthan AFB boneyard into remotely piloted UCAVs. However, this interim UCAV proposal must overcome critical hardware problems with the F-16A and the high cost of implementing a new weapons system into the USAF inventory. Designed in the early 1970s, F-16A models have no night or precision ordnance capability except for the AGM-65 Maverick missile. To update its antiquated avionics to current F-16C ordnance and main-



*F-16As in storage at Davis-Monthan AFB, Tucson, Arizona*

tenance standards may require up to five million dollars per aircraft. In addition, the USAF does not have the money or personnel resources during a pilot shortage to quickly bring an F-16A-model UCAV program to operational status.

To avoid many of the problems and costs associated with the LMTAS F-16A UCAV proposal, another F-16 UCAV option is to modify currently flying Block 40 and 50 F-16Cs into "dual-role" manned and UCAV aircraft. A dual-role F-16 will retain all of its original manned fighter capability with the addition of less than three hundred pounds of remote-control and communications equipment. If called upon to perform its unmanned role, the UCAV aircraft is immediately available with no additional maintenance. Initially, the USAF should convert only four to six jets in selected operational low-altitude navigation and targeting infrared for night (LANTIRN) system and SEAD F-16C squadrons into dual-role UCAV aircraft. This will reduce initial program costs and ease the transition to unmanned aircraft operations by training only a few pilots and maintenance personnel in dual-role operations and support. As unmanned flight operations and support become more routine, additional squadron aircraft can convert to dual-role status and more pilots and maintenance personnel can cross-train into the program.

#### ***Design Modifications***

To give an F-16C a part-time UCAV capability requires two areas of modification: flight controls and communications. Engineers need to incorporate an auto-throttle and auto-land capability into the flight controls similar to the design proposal for the Block 60 F-16. Additional communications equipment for the F-16C is needed for remote-control operations and sensor feedback to the ground operator. Lockheed has already designed a communications satellite (SATCOM)-equipped F-16 for international customers. One possible location for engineers to put additional datalink hardware is in the vertical fin base originally designed to hold the canceled USAF airborne self-protection jammer (ASPJ) internal electronic warfare (EW) project. Rough estimates from QF-4 conversion experts put basic F-16 UCAV flight control and auto-landing recurring costs at three hundred to four hundred thousand dollars.<sup>10</sup> Adding SATCOM and additional secure datalinks and antennas would add two hundred to three hundred thousand dollars of recurring costs.

If the UCAV mission required additional combat range, maintenance can remove the seat and replace it with a twenty-three-hundred-pound cockpit fuel tank in a matter of hours. If future unmanned missions require F-16C

UCAV air refueling, one proposal is to add a small camera near the heads-up display (HUD) at a lookup angle so the remote ground or tanker-based operator could fly off the refueling position lights mounted on the tanker bottom.

#### ***Benefits of the F-16C UCAV***

The F-16C UCAV proposal can quickly and effectively fulfill the requirements for an interim UCAV because of low program cost, low risk, and small impact on USAF integration. Additional dual-role F-16C benefits include increased survivability, high combat-readiness rates, and a better global-response capability.

Usually, the most important part of any new weapons system program is cost. The F-16C dual-role UCAV keeps costs low by modifying existing operational aircraft and by using the current worldwide billion-dollar F-16C infrastructure. Slightly modifying currently flying F-16Cs into dual-role UCAVs will be less expensive than the millions of dollars required to return to flight status the mothballed F-16A or develop a new aircraft. Since the F-16C is compatible with most current weapons systems, research, development, and testing would save money by focusing only on the remote-control interface and UCAV concept of operations. Sharing the current operational F-16C infrastructure will provide substantial savings compared to the normal start-up costs of a new weapons program, including Block 40 laser-targeting pods and Block 50 HARM targeting-system pods. Current manned F-16 operations budgets would absorb most UCAV costs involved with daily peacetime training, flight operations, and maintenance support. By using the current F-16C aircraft and its support infrastructure, the Air Force can make the dual-role F-16C a cost-effective interim UCAV.

In addition to cost-effectiveness, a UCAV program utilizing the current F-16C infrastructure greatly reduces the impact on the USAF in manning and combat-readiness issues. During a pilot shortage, the USAF cannot afford to transfer combat-qualified F-16 pilots to a new UCAV squadron. If the Air

Force initially converts just four to six F-16Cs into dual-role aircraft, current squadrons can maintain combat-readiness status since they need to train only a few pilots and maintenance personnel in UCAV operations. Over time, with increased experience and more confidence in unmanned operations, if needed, the USAF can convert more F-16C aircraft into dual-role UCAVs. In addition to manning and combat readiness, slowly integrating a few UCAV-capable aircraft into the current F-16C infrastructure will reduce the predictable negative reaction from fighter and bomber pilots to lethal unmanned combat operations. Once F-16C UCAV flight operations become routine, the rated Air Force will see the advantages of remote-control flight and better accept the eventual transition of the USAF from a manned to unmanned combat force.

In addition to cost-effectiveness and USAF impact, the dual-role F-16C benefits from increased survivability, high combat-readiness rates, and a better global-response capability. Survivability is the key to reusability, which makes UCAVs more cost-effective than cruise missiles. With a modern radar, AMRAAMs, a good threat-warning receiver, countermeasures dispensers, towed decoys, and other self-protection capabilities, the Block 40/50 F-16C is a survivable aircraft. High combat-readiness rates for the UCAV will automatically mirror the manned F-16C combat force, with "code 1" maintenance ready rates, the highest among fighters in the USAF. Another benefit of the F-16C UCAV is the ability to rapidly respond to any global crisis. The F-16C would avoid current UCAV air refueling, diplomatic clearance, and air traffic control (ATC) problems by flying across the ocean as a manned aircraft. After landing, the aircraft requires no maintenance to immediately fly an unmanned mission, if needed.

#### ***F-16C UCAV Concerns***

The primary obstacle for an F-16C UCAV program is limited combat range without air refueling. Manned F-16s can bomb targets thousands of miles away on missions with pre- and poststrike air refueling. Most UCAV support-

ers, including LMTAS, believe that unmanned air refueling, controlled either from the ground or by the tanker boom operator, is feasible with today's technology. However, manned F-16 air refueling requires numerous, rapid flight-control corrections and is considered a difficult pilot task, especially at night or in poor weather conditions such as clouds or turbulence. In addition, air refueling puts unmanned aircraft within a few feet of a US high-value asset with no room for error. Therefore, even with advanced technology, many years of testing and, more importantly, KC-135 and KC-10 manned tanker acceptance are needed for UCAV remote-control air refueling.

To extend combat range without air refueling, one can increase the F-16C UCAV's ground fuel load in several ways. In addition to the twenty-three-hundred-pound cockpit fuel tank previously mentioned, several overseas F-16 customers are planning to fly with six-hundred-gallon wing fuel tanks and the recently tested four-hundred-gallon conformal fuel tanks (CFT) on top of the wing roots. However, USAF F-16 pilots prefer the standard 370-gallon wing fuel tanks because the six-hundred-gallon wing tanks severely limit aircraft performance. Table 3 shows the approximate combat radius for a Block 42 F-16C carrying two two-thousand-pound LGBs and for a Block 52 F-16C carrying two HARM missiles. The F-16C computer flight-planning system (CFPS) version 2.0 computed both aircraft flying at .85 Mach carrying wingtip

AMRAAMs and a centerline ALQ-184 electronic counter-measures pod.

For the LANTIRN and F-16C UCAVs with the HTS, the use of six-hundred-gallon wing tanks and the cockpit fuel tank gives over a 50 percent increase in combat range without air refueling over the standard 370-gallon wing tank configuration. However, with this increase in range, the UCAV increases the radar cross section and suffers decreased combat maneuverability that may lower survival chances in high-threat areas.

Other F-16C UCAV proposal concerns are the same as those for future advanced-technology UCAV aircraft previously mentioned in table 2. The use of automation in the F-16C UCAV C<sup>2</sup> loop will prevent aircraft mishaps due to datalink termination. If datalink is lost, the F-16C UCAV can automatically continue up to weapon release, waiting for datalink reconnection, or it can return to the launch base and execute an automatic landing. As previously mentioned, flight testing of manned aircraft with a remote-control interface will alleviate many of the concerns listed in table 2 and build USAF confidence in UCAV operations.

### Implementation of the F-16C UCAV

With low modification costs, low risk, no new infrastructure, and minimal training, the USAF should immediately start planning for

**Table 3**

**F-16C Combat Radius**

<b>Fuel Tanks (internal fuel 6,900 lb)</b>	<b>F-16C Block 42 (navigation pod and targeting pod) (2) GB-10C Cruise 25,000 ft</b>	<b>F-16C Block 52 HARM Targeting System (HTS) (2) HARM Cruise 30,000 ft</b>
Current 370 Wing Tanks	450 Nautical Miles (NM)	525 NM
370 Wing + Cockpit Tank	550 NM	650 NM
600 Wing Tanks	600 NM	700 NM
600 Wing + Cockpit Tank	700 NM	800 NM



*F-16C firing AMRAAM*

the development, testing, and modification of F-16C aircraft into dual-role LANTIRN and HTS-capable UCAVs. To quickly field an F-16C UCAV program, the USAF must prioritize with increased funding for UCAV research in three critical areas: (1) the F-16C aircraft modification, (2) the remote-control ground station, and (3) development of a concept of operations (CONOPS).

#### ***F-16C Aircraft Modification***

The modification of the F-16C into a dual-role manned-and-unmanned-capable fighter requires the addition of off-the-shelf SATCOM and datalink communications equipment and antennas. DARPA is currently planning with LMTAS the modification of the Advanced Fighter Technology Integration (AFTI) F-16 as a UCAV technology demonstrator.<sup>11</sup> With additional information on remote-control equipment and operations from the QF-4 aerial drone squadron at Tyndall AFB, LMTAS can quickly design plans for the USAF to modify at least one Block 42 LANTIRN and one Block 52 HTS F-16C as unmanned flight demonstrators.

As previously mentioned, initial flight testing of a remote-control interface with pilots having override authority in the cockpits will alleviate many unmanned-operation con-

cerns. One possibility is for pilots from the 85th Test and Evaluation Squadron at Eglin AFB to fly the demonstrator F-16Cs utilizing the Tyndall AFB ranges with existing remote-control facilities and the drone runway. More advanced “battlefield” testing for weapons and communications jamming should occur at the Nevada ranges from either Nellis AFB or from Indian Springs Airfield, Nevada, using Predator ground-station facilities.

#### ***Ground-Station Design***

The design of the F-16 remote-control ground-station “cockpit” must start prior to aircraft testing. The large and expensive F-16 visual simulators used to train new pilots are not needed and are not deployable. The baseline for a small, deployable F-16 UCAV ground station should be a single visual-screen unit training device (UTD) or part task trainer (PTT). Numerous UTDs and PTTs are currently used for F-16 training worldwide and are exact cockpit duplicates of the F-16 with a video screen behind the HUD. For a UTD or PTT to become a remote-control UCAV ground station, engineers must integrate datalink and communications equipment with the simulator computers. These small cockpit UTD or PTT simulators with their associated computers, video monitors, and

datalink/communications equipment can easily fit onto one airlift cargo pallet.

Does every switch and light in this remote-control UCAV ground station need to work? Should the pilot look at the current small four-by-four-inch F-16 multifunction display (MFD) or at 27-inch TVs around the cockpit? LMTAS may have the answers to some of these questions from several years of testing in its F-16 UCAV simulator in Fort Worth, Texas. Additional human-factors-engineering testing with LMTAS and F-16 pilots will provide the optimal compromise between mission effectiveness and a small, cost-effective, and deployable ground-station design.

#### *Concept of Operations*

The USAF should form a working group with personnel from the Predator squadron at Indian Springs, the QF-4 drone squadron at Tyndall AFB, the Eglin AFB UAV battlelab, and LMTAS, as well as USAF Weapons School instructors at Nellis AFB to develop an F-16C UCAV concept of operations. CONOPS development will initially attempt to answer many of the concerns in operating an unmanned F-16 such as air traffic control interaction and concerns about whether the F-16 UCAV should carry AMRAAMs. CONOPS development will define which mission areas require direct operator control, semiautonomous control, or UCAV fully autonomous control. The use of more autonomous and semiautonomous control of UCAVs will minimize communications bandwidth availability problems and reduce enemy EW detection.

If the USAF provides the necessary funding, then simultaneous research, development, and testing of the aircraft, ground station, and CONOPS can put F-16C dual-role UCAVs into operational squadrons in just a few years. The F-16C UCAV idea will require a small budget investment compared to normal Pentagon acquisition programs, and the interim F-16C UCAV is a low-risk investment. Even if the program suffers setbacks or is canceled, the USAF retains its manned F-16 infrastructure, and modified aircraft are easily returned to a "manned-only" status.

## Future F-16C UCAV Missions

If an F-16-compatible deployment base is within eight hundred miles of potential targets, then US leadership and military planners will use aircrew risk and target type as two key considerations for the decision of whether to use cruise missiles, UCAVs, or manned aircraft to attack a target. Total aircrew risk is the combination of political risk and military combat risk. Even if the military risk due to few enemy threats and good weather is small, the political consequences of aircrew loss or collateral target damage may be too high. Likewise, in major conflicts with lower political risk for aircrew death, capture, or collateral damage, advanced SAMs, lack of air superiority, or poor weather may drive the military risk too high for manned flight. If the combination of political and military risk is high, target type will dictate the use of cruise missiles or UCAVs. Table 4 lists the most cost-effective weapons platform depending on risk, target size, and type.

USAF planners should use manned aircraft for all low-threat political and military missions because they are the most cost-effective and capable airpower tool. Because of current cruise missile CEP accuracy, UCAVs or manned aircraft with penetration LGBs are best for smaller hardened targets where the bombs need to "go down the air vent." An interim F-16C UCAV is the weapons system of choice if the political or military risk is high and the target is not cruise-missile capable. Because of the need for SEAD in military high-risk areas, F-16C UCAV CONOPS must address the coordination of both Block 40 LGB and Block 50 HARM unmanned aircraft.

## Conclusions

Technology is taking the human out of the fight. In the near future, unmanned Army tanks, Navy ships, and Air Force aircraft will conduct battles controlled by operators hundreds or even thousands of miles out of harm's way. Advancing technology, smaller post-cold-war budgets, and political pressures

**Table 4**  
**Weapon-System Selection**

Target Type	Military + Political Risk		
	High	Medium	Low
Soft	Cruise missiles	Cruise/UCAVs	Manned aircraft
Large Hardened	Cruise missiles*	Cruise*/UCAVs	Manned aircraft
Small Hardened	UCAVs**	Manned/UCAVs	Manned aircraft
Bridges/Armor	UCAVs**	Manned/UCAVs	Manned aircraft
Mobile/SEAD	UCAVs**	Manned/UCAVs	Manned aircraft

\*If proposed hard-target penetration capability is available; otherwise, UCAV with LGBs

\*\*Block 50 HTS UCAV SEAD may be needed for survival of Block 40 UCAVs

have convinced many scientists and military planners to push for research and development of unmanned systems despite the resistance to change from some leaders in the Pentagon. Because of past success stories and the current dependence of military commanders on the valuable battlefield information provided by systems such as Pioneer and Predator, the future funding of new UAV surveillance and reconnaissance platforms is assured. However, budget competition from the manned F-22 Raptor and Joint Strike Fighter programs has limited research and development funding and Pentagon enthusiasm for lethal UCAVs. Current estimates put the operational fielding of an advanced-technology UCAV system decades away.

In addition to cruise missiles, does the United States now need another unmanned lethal military option? Yes, the political, economic, and military benefits of quickly fielding an interim UCAV system are worth the additional funding. Similar to the important political advantages of cruise missiles, interim UCAVs do not expose US aircrews to the risk of death or capture, which also eliminates the need for CSAR resources. Unlike cruise missiles, however, reusable UCAVs may provide a more economical military option in certain

situations than a one-shot, million-dollar-plus Tomahawk. Militarily, an interim UCAV provides more ordnance and target capabilities than cruise missiles, especially against smaller hardened structures and mobile targets. UCAVs also provide the military with a man-in-the-loop capability to identify target areas and give consent prior to ordnance release. In addition, the important CONOPS "lessons learned" and the resolution of other future unmanned flight concerns will greatly ease the transition of the USAF into an advanced-technology unmanned combat force later in the twenty-first century. A successful interim UCAV program will be an important stepping stone for the transition from a manned to an unmanned combat Air Force. For these political, economic, and military reasons, the United States needs an interim UCAV capability until advanced-technology unmanned combat forces are operational.

Can the USAF provide a quickly fielded, cost-effective, and capable interim UCAV? Yes, a dual-role F-16C UCAV is the answer. Converting four to six Block 40 LANTIRN or Block 50 HTS aircraft in current operational squadrons to dual-role manned and unmanned F-16Cs will provide a cost-effective and capable UCAV option that the USAF

could quickly field. The F-16C UCAV is cost-effective not only because the simple aircraft modification is the addition of off-the-shelf communications and remote-control equipment; more importantly, it uses the existing F-16 infrastructure. The use of the current F-16C airframe, support and operations facilities, and maintenance, plus pilot "operator" workforce, would eliminate expensive new

weapons system start-up costs, including the training of additional personnel.

The F-16C Block 40 and 50 dual-role UCAV is a "can't lose" proposition. With a small program investment and limited risk, there is a huge potential payoff. The USAF should immediately start funding research and development for the operational fielding of F-16C UCAVs. □

#### Notes

1. Mark Walsh, "Battlelab of Drones That Can Kill," *Air Force Times* 57, no. 52 (28 July 1997): 27.
2. David A. Fulghum, "Groom Lake Tests Target Stealth," *Aviation Week & Space Technology* 144, no. 7 (5 February 1996): 27.
3. Slide presentation with notes, Col Michael Francis, Defense Advanced Research Projects Agency, n.p.; on-line, Internet, 1996, available from <http://www.arpa.mil/ARPATech-96/slides/francis/100/1.gif>.
4. Col Bruce W. Carmichael et al., "Strikestar 2025," a research study presented to the Air Force 2025 Study Group (Maxwell AFB, Ala.: Air Command and Staff College, August 1996), n.p.; on-line, Internet, 1999, available from <http://www.au.af.mil/au2025/volume3/chap13/v3c13-1.htm>.
5. Bill Sweetman, "Pilotless Fighters: Has Their Time Come?" *Jane's International Defence Review* 30, no. 6 (June 1997): 59-68.
6. Gen Ratko Mladic, as quoted in *New York Times*, 16 July 1995, A6.

7. "Tomahawk Cruise Missile Fact Sheet," US Naval Office of Information, Navy Public Affairs Library, Washington, D.C., April 1993, n.p.; on-line, Internet, 1999, available from <http://www.chinfo.navy.navpalib/weapons/missiles/tomahawk/facts.txt>.
8. James Burda, USAF Armament Production Group manager, Eglin AFB, Fla., *Precision Guided Munitions*, n.p.; on-line, Internet, 1999, available from <http://www.issues.af.mil/pgm.html>.
9. Dr. Robert Finkelstein, "Unmanned Aerial Vehicles Seminar Study Guide," study guide for the UAV Seminar, Washington, D.C., 17-18 November 1997 (San Diego, Calif.: Technology Training Corporation, 1997).
10. Ibid.; see also Air Force Audit Agency, *Full Scale Aerial Target Acquisition and Logistical Support* (Washington, D.C.: Air Force Audit Agency, 1997), 2.
11. David A. Fulghum, "ARPA Explores Unmanned Combat Aircraft Design," *Aviation Week & Space Technology* 144, no. 9 (26 February 1996): 23-25.

---

*Being ready is not what matters. What matters is winning after you get there.*

—Gen Charles Krulak